Flight Systems Research Quarterly

An informal newsletter by and for participants of the UCLA/NASA Flight Systems Research Center

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Balakrishnan Honored by NASA

At the 1996 NASA Honor Awards Ceremony held at Dryden on May 16, Professor A.V. Balakrishnan of UCLA's Department of Electrical Engineering was awarded the NASA Public Service Medal.

The guest speaker for the ceremony was Gen. John R. Dailey (UCLA '56), Acting Deputy Administrator of NASA. Along with Dryden Director, Kenneth J. Szalai, Gen. Dailey presented Prof. Balakrishnan with the award which read: "In recognition of exceptional continuous theoretical and administrative contributions in establishing the UCLA-NASA Flight Systems Research Center to create increased research interactions between the university community and NASA." Last year ('95-'96) marked the 10th anniversary of the FSRC.

"Hyper-X" to Flight Test Scramjet Engine

NASA is poised to begin a multi-year hypersonic flight-test program by requesting proposals from industry for the fabrication of four unpiloted research aircraft that will fly up to ten times the speed of sound. The contract award is scheduled for early 1997.

The selected contractor will be responsible for fabrication and flight-test support of the hypersonic experimental research vehicles to be called "Hyper-X."

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Dryden Plays Major Role in X-33

NASA's Dryden Flight Research Center plays a prime role in the development and flight testing of the new NASA/Lockheed Martin X-33 technology demonstrator for a Single-Stage-to-Orbit (SSTO) Reusable Launch Vehicle (RLV). A total of 15 suborbital flights are scheduled for the X-33 program with the first scheduled for early 1999.

The NASA/Lockheed Martin X-33, pictured in artist's rendering. NASA photo EC96-43631-2.

"Dryden will participate in the newest and most challenging experimental aircraft program. Under a new Cooperative Agreement, NASA has shifted gears and is working with Lockheed Martin in developing the X-33 technologies, instead of just managing the program," according to Gary Trippensee, Dryden's X-33 project manager. "This arrangement is expected to be the norm for the new RLV systems," Trippensee said.

Dryden's participation includes: flight test planning, flight control development and real-time simulation, which consists of installing new flight control components on a stationary test stand called an "Iron Bird," in order to realistically test the operation of the controls and associated computer software.

Dryden and the U.S. Air Force Flight Test Center at Edwards AFB are responsible for the construction of a new tracking range extending from Edwards to Malmstrom AFB, MT, and other potential sites. Currently, Bicycle Dry Lake, located 80 miles northeast of Dryden, is scheduled as the first-flight landing site of the X-33.

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In this issue

NASA NEWS AROUND DRYDEN

High Angle-of-Attack Conference Looks Back

The NASA High Angle-of-Attack Technology Program (HATP), which began in 1985 to explore high angle-of-attack (AOA) issues relating to the design of future highly maneuverable fighter aircraft, was brought to a conclusion at the Fifth High Angle-of-Attack Technology Conference held Sept. 17-19 at the Langley Research Center, Langley, VA.

More than 200 participants from various NASA centers, the Department of Defense, universities, and industry convened to make their final reports about the ground and flight test results of the HATP, summarize lessons learned, discuss other national programs, and plot future directions for research in the high-AOA area.

Since the start of the HATP, Dryden has been responsible for flight testing with the F-18 High Angle-of-Attack Research Vehicle (HARV). This year, Dryden sent 13 people and eight papers to the conference, according to Dryden's HARV program manager, Denis Bessette. The F-18 HARV was also flown to the conference and was well received by all.

In recent years, UCLA has contributed to the HARV program in several areas, including the application of parameter-robust, game theoretic synthesis to the HARV (Prof. Speyer; Chuck Dillon),

(Continued on page 3)

LoFLYTE Tests Waverider Configuration

The LoFLYTE aircraft arrived at NASA Dryden on August 6, in preparation for a series of flight tests which are scheduled to begin this fall. The 8-foot-4-inch long remotely piloted, jet-powered aircraft will explore the low-speed flight characteristics of its futuristic waverider design. Second and third technology demonstrators may be used for other test phases.

The 70-pound aircraft is based on the design of a Mach 5 waverider - a hypersonic aircraft configuration that actually cruises on top of its own shockwave, providing inherently high hypersonic lift-to-drag. Waverider aircraft, powered by airbreathing hypersonic engines, would fly at speeds above Mach 5, altitudes over 90,000 feet, and have cruise ranges of up to 8,000 miles. LoFLYTE represents the first known flying waverider vehicle configuration. Flight tests at Dryden will be flown only at low subsonic speeds to explore takeoff and landing control issues.

The waverider design was also chosen as a testbed to explore new flight control techniques involving neural networks, which allow the flight control system to learn by mimicking the pilot.

The aircraft's flight controller consists of a network of multiple-instruction, multiple-data neural chips. The network will be able to continually alter the aircraft's control laws in order to optimize flight performance and take the pilot's responses into consideration. Over time, the neural network system

(Continued on next page)

X-36 Fighter Arrives at Dryden

The X-36 Tailless Fighter Agility Research Aircraft arrived at Dryden on July 2. The X-36 is a small, remotely-piloted jet built by the McDonnell Douglas' Phantom Works division of St. Louis, Mo., and is designed to fly without the traditional tail surfaces common on most aircraft.

"The arrival of the X-36, along with the program staff from McDonnell Douglas and NASA's Ames Research Center at Moffett Field, Calif., is an important milestone for the program," said Berwin Kock, Dryden's X-36 Project Manager. "The entire team is looking forward to getting this marvelous machine into the air and thereby continuing the X-airplane legacy of discovery and understanding."

The X-36 is 18 feet long with a 10 foot wingspan, is 3 feet high, and weighs 1,270 pounds. The aircraft is powered by a Williams Research F112 turbofan engine that provides 700 pounds of thrust.

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(Hyper-X..., continued from page 1)

The Hyper-X Phase I program is conducted jointly by NASA's Langley Research Center and Dryden Flight Research Center. Program managers hope to demonstrate key propulsion and related technologies applicable to future air-breathing hypersonic aircraft and reusable space launchers. Heading the list is the demonstration of a ramjet/scramjet engine, followed by validation of design tools and methods for air-breathing hypersonic vehicles.

"It's time to fly. This exciting, challenging, ground and flight research program will significantly expand the boundaries of air-breathing flight for the first time ever, by flying a scramjet-powered aircraft at hypersonic speeds," said Vince Rausch, the Hyper-X Phase I program manager.

Hyper-X, measuring approximately 12 feet long with a wing span of about five feet, will ride on the first stage of a Pegasus booster rocket, which will be launched by the Dryden B-52 at about 40,000 feet. For each flight, the booster will accelerate the Hyper-X vehicle to test conditions (Mach 5, 7, or 10) at approximately 100,000 feet, where it will separate from the booster and fly under its own power.

Four flights are planned - one each at Mach 5 and 7 and two at Mach 10. The flight test will be conducted within the Western Test Range off the coast of southern California.

(LoFLYTE..., continued)

could be trained to control the aircraft. The use of neural networks in flight would help pilots fly in quick-decision, high-stress situations and help damaged aircraft land safely even when the controls are partially destroyed.

Dryden's role in the LoFLYTE program is primarily hosting and providing range support for the flight tests with the aircraft's developer, Accurate Automation Corp. of Chattanooga, Tenn.

The program is being administered through NASA's Langley Research Center, Hampton, Va., and the Air Force Wright Laboratory, Dayton, Ohio, under the Small Business Innovative Research Program. The initial configuration for the aircraft was developed at NASA Langley.

(X-33..., continued from page 1)

The first flight will be a flight envelope expansion up to speeds of Mach 3. Michaels Auxiliary Airfield, UT, is scheduled as the second-flight landing site, another envelope expansion flight, this time up to Mach 7. The third and fourth flights will complete the envelope expansion series, with speeds up to Mach 15, culminating with landings at Malmstrom AFB. The remainder of the flights are scheduled to land at Malmstrom, with flight testing to include thermal cycling, aerodynamic development, and operational issues.

Dryden will plan and provide for range safety, which includes making sure the vehicle stays on course. Dryden will also share in the construction of new launch facilities at Edwards. In addition, Dryden will assist with modification to the 747 Shuttle Carrier Aircraft (SCA) that will transport the X-33 back to Dryden from Malmstrom AFB, and possible Mate-Demate Device (MDD) modifications.

Dryden and Lockheed Martin will continue the Linear Aerospike SR-71 Experiment (LASRE), which is an effort to flight test a linear aerospike rocket engine for the first time.

The Reusable Launch Vehicle technology program involves a cooperative agreement between NASA and industry. The goal of the RLV technology program is to enable significant reductions in the cost of access to space, and to promote the creation and delivery of new space services and other activities that will improve U.S. economic competitiveness.

The RLV program consists of the X-33, the smaller X-34, and the McDonnell Douglas Graham Clipper DC-XA. Orbital Sciences Corporation will build the X-34 and plans to launch the rocket from its L1011 aircraft. The X-34 will be capable of flying at eight times the speed of sound and reach an altitude of 250,000 feet and make up to 25 flights per year. New technologies such as composite structures and advanced landing systems will also be tested. The Graham Clipper is the first rocket ever to fly with a composite hydrogen tank and associated composite intertank (between the hydrogen and oxygen tanks), plumbing lines, and valves. The Clipper Graham has flown four successful low-altitude flights through July 31.

(High Angle-of-Attack..., continued)

integration and analysis of wing and tail surface pressures for the HARV (Prof. Speyer; John Griswold), probabilistic risk assessment and fault management applied to the HARV research flight control system (Prof. Apostolakis; Chris Garrett), estimation of air data parameters during dynamic flight (Prof. Levan; Logan Brashear), and in the development of neural network flush airdata systems (Prof. Catton; Tom Rohloff - see p. 4).

UCLA FSRC Research Roundup

The following summaries were provided by graduate student researchers and/or their professors.

Computations of Unsteady Flows Over Low-Reynolds Number Airfoils

PI: Prof. Xiaolin Zhong (MAE)
GSR: Mahidhar Tatineni TM: Al Bowers

Low-Reynolds-number flows over airfoils are characterized by the presence of separation bubbles which have significant effects on aerodynamic parameters such as the lift and drag coefficients. We are conducting time-accurate numerical simulations of flows in this regime using the Favre averaged Navier-Stokes equations with turbulence and transition modeling. The computations are also done using the laminar Navier-Stokes equations for the purpose of comparison. The studies are motivated by the Dryden APEX high altitude flight experiment to collect aerodynamic data for high subsonic/transonic Mach number and low-Re flows.

The separation bubble is usually assumed to be steady, but our results reveal that under certain conditions the separation bubble can be unsteady with vortex shedding. The results of computations over the Eppler 387 airfoil are compared with existing experimental data. The time-accurate results show periodic vortex shedding in the separation bubble. The numerical time-averaged lift and drag coefficients agree well with the experimental data which can be considered to be time-averaged. The results suggest that the prediction of the unsteady nature of the separation bubbles is important for accurate calculations of low-Re flows over airfoils. Current research is focused on the computations of subsonic/transonic low-Re flows over the APEX airfoil. The size and unsteadiness of the separation bubbles is strongly affected by the prediction and modeling of transition. We are currently studying the effects of the transition location on the separation bubbles and the overall aerodynamic parameters for the APEX airfoil.

Analytical Approach to Strategic Planning

PI: Dr. Harold Mortazavian (EE)
TM: Dwain Deets

During the past few months our research has been focused on solving a number of problems related to strategic planning and decision-making for optimal utilization of human resources, and development of a highly practical software tool based on these results, written in Microsoft Excel. Specifically, building upon the work of the previous year , we present the solution to the following problem: given a set of tasks that partially overlap in time, and given a set of skill categories and the information on the skills required to perform each task, find the minimum number of workers per skill category required, under a variety of time constraints. We also obtained the solution to the reverse problem: given an initial set of tasks with prescribed priorities and specified skill requirements, and given data on man-hour/skill availability, choose and schedule projects that can be performed. We then relate this problem to another important problem namely that of limiting fluctuations on each skill category utilization over time between an upper and a lower bound. The implemented solutions are highly efficient from the point of view of computational complexity.

Development of Neural Network Flush Airdata Systems

PI: Prof. Ivan Catton (MAE)
GSR: Thomas Rohloff TM: Dr. Tony Whitmore

Neural network techniques are being applied in the development of flush airdata instrumentation. The complex model that is typically applied in the FADS transformation can be replaced by using flight data to train a multi-layered, feedforward neural network. Using a modified back propagation training algorithm, a neural network has been developed to represent the mapping between the pressure-matrix-input and the airdata-output vector spaces for a subsonic portion of the flight envelope of the F-18 HARV. The performance of this network has been found to be as good as the FADS algorithm for the flow regime being considered. The next step in this investigation is the extension of the input range of the neural network to cover the entire flight envelope of the test aircraft, including the transonic and supersonic flow regimes. Techniques are being developed to enhance and evaluate the robustness of the neural network based FADS system.

Non-Intrusive Surface Measurement Methodology

PI: Prof. Ivan Catton (MAE)
GSRs: John Mendoza, E. David Huckaby
TMs: Rodney Bogue, Bob Curry

Development of non-intrusive methods of measuring flow details (temperature, pressure, and velocities) are continuing. The preliminary focus is on temperature and the use of optical methods to obtain the necessary information. In looking at several methods (liquid crystals, Laser-holographic Interferometry, and laser induced oxygen fluorescence), it was found that the latter best suits our purpose due to its robustness and quick response. The LIF method, using broad-band excitation and detection, will be done by using a Xenon flashlamp to excite oxygen molecules. The temperature and pressure will be derived from the emitted fluorescence. Currently, selection of the proper bandwidth windows (windows for which the fluorescence is sensitive to either temperature or pressure but not both) via a numerical program that generates the fluorescence spectrum of the oxygen molecule is being developed. Concurrently, an experiment is being put together to test the method in the laboratory wind-tunnel.

(Continued on next page)

Analytical Approach to Gain-Scheduled PID Flight Control System Design

PI: Prof. Robert T. M'Closkey (MAE)
GSR: Joel Krajewski TM: Joe Pahle

The design of gain-scheduled MIMO PID control laws is first simplified to the case where the aircraft model is a fixed linear system. Thus we are seeking methods to yield constant gain, multivariable PID controllers. In this case the bounded real lemma is used to specify an $\mathcal{H}_\infty$ performance objective on the closed loop system. This is a convenient framework in which to work since many competing design objectives can be treated concurrently. The computational problem reduces to a biaffine matrix inequality in the Lyapunov function variables and controller gains. This is a non-convex optimization problem and a number of search techniques for finding the global optimum are being considered. We are currently exploring branch-and-bound techniques to efficiently compute solutions.

Analytical Redundancy, Fault Detection, and Health Monitoring for Aircraft

PI: Prof. Jason L. Speyer (MAE)
GSR: Walter H. Chung TM: Dr. Ken Iliff

A health monitoring system is a system which autonomously checks the overall system (such as an airplane) for irregularities which may be indicative of failures in the sensors, actuators, or physical structure of the overall system. There are many different schemes for health monitoring, but in general they all rely on comparing measurements taken from the system with similar signals generated from a nominal model of the system. In this research, we have looked at health monitoring schemes based upon a special type of observer called a fault detection filter. Previously, we devised a new approach to fault detection filter design which extends the applicability of the fault detection filter to time-varying systems and which allows the designer to make trade-offs for better noise rejection or disturbance attenuation. Since then, we have demonstrated the filter on a time-varying system via simulation and we have developed a variation on the filter which is robust to plant parameter uncertainty. In future work, we will look at the implementation of this filter on distributed systems such as a formation of airplanes or a platoon of cars.

In-Flight Imaging of Lobed Injector Mixing Processes

PI: Prof. Owen I. Smith (MAE)
Co-PI: Prof. Ann R. Karagozian (MAE)
Postdoc: Lance L. Smith (through June, 1996)
GSRs: Ari Majamaki, Mark Mitchell, Ivan Lam
TM: Al Bowers

Laboratory scale experiments are establishing the mixing and reaction processes occurring in the flowfield of a lobed fuel injector, a novel fuel injector/burner which has the potential for significant reduction in NOx emissions from aircraft engines (eg. for the HSCT and AST) . Mixing experiments were conducted by Dr. Lance Smith with grad students Ari Majamaki and Ivan Lam, in which acetone Planar Laser Induced Fluorescence (PLIF) was used to visualize the 2D concentration fields evolving from the lobed injector as a function of the streamwise coordinate. Comparison was made between alternative lobed injector designs and a straight fuel injector. Scalar dissipation rates were calculated from the scalar concentration fields, and associated strain rates were estimated in the flowfield, indicating that substantial mixing and ignition delay could occur in a reactive context.

Combustion experiments in the laboratory are being conducted by Mark Mitchell, using lobed as well as straight fuel injectors and rearward-facing step flameholders. The lobed injector is seen to produce at least partially premixed, lean flames with relatively low NOx emissions. In contrast, the straight injector (which generates little streamwise vorticity except further downstream) produces much longer, sooting diffusion flames, with NOx emissions that can be higher. This study is continuing, with plans for PLIF imaging of the OH radical in the reactive flowfield. Numerical modeling of strained fuel layers (see below) will assist in relating combustion data to non-reactive mixing data.

In-flight experiments on a NASA F-15 aircraft will examine the lobed injector mixing processes at much higher speeds (Mach 0.3-0.8), for application to high speed mixing and combustion processes in aircraft engines. Ari Majamaki is working with Professors Smith and Karagozian as well as with Greg Noffz of NASA Dryden to design the flight test fixture, which will include an on-board Nd-YAG laser to conduct in-flight acetone PLIF experiments. In-flight iodine PLIF has been performed successfully at Dryden in the past by Professors Smith and Karagozian, working with former UCLA grad student Charles Wang. The present experiments are anticipated to be able to characterize high speed lobed injector mixing processes, from which combustion characteristics may be extracted using a numerical model.

Modeling of a Lobed Injector/Burner

PI: Prof. Ann R. Karagozian (MAE)
GSRs: Thomas Selerland, Timothy Gerk (M.S. March, 1996) TM: Dr. Stephen Corda

Former M.S. student Tim Gerk developed a numerical model for mixing processes associated with the lobed injector. He also performed an asymptotic analysis of the ignition delay process for a component of the injector flowfield (the strained fuel strip) using one-step activation energy asymptotics for the combustion chemistry. The combustion portion of this study reveals different modes of ignition that have previously not been observed.

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(Research Roundup, continued)

Thomas Selerland, a Ph.D. student, is currently studying ignition, burning, and extinction processes associated with this component of the lobed fuel injector, using full propane-air combustion chemistry; he sees similar modes of ignition to those predicted by the asymptotic analysis. This computational methodology will be used directly in the procedure to apply strain field data from the laboratory mixing experiments to an equivalent combustion experiment. The procedure will ultimately be used in reducing flight test data. The strain field data from these mixing experiments will be inputted into Thomas' numerical model to be able to predict combustion characteristics of the lobed injector flowfield. The ignition modeling will also be used in a full-scale numerical simulation of the lobed injector/burner, which will assist in the design and testing of alternative geometries for future experimental prototypes.

Design and Evaluation of a Multimedia Information Display for Real-time Monitoring of Flight Test Data

PIs: Prof. Walter J. Karplus (Comp. Sci.)
Prof. Jerry D. Balakrishnan (Purdue Univ.)
GSR: George Khadder
Rajesh Venogopalan TM: Mary Shafer

In a typical flight test, the flight test engineer must attend simultaneously to a number of different speech signals. At different times, the relative importance of these signals may change, and the problem is therefore to selectively attend to them in an efficient way. In our project, we are examining the potential benefits of using three-dimensional audio display technology to spatially separate these signals. The system we are developing allows the operator to define a virtual sound space, with the different speakers and the listener located at different positions in the space. The listener may also be a speaker, and the configurations chosen by the listeners will be completely independent of one another. The listener can move within the space, and their nearness to a source determines the amplitude of the source relative to the others. The ultimate goal is to develop a simple, low cost methodology that requires minimal training.

Studies in Transonic Aeroservoelasticity

PIs: Prof. Peretz P. Friedmann (MAE)
Prof. Oddvar O. Bendiksen (MAE)
GSR: Guang-Yaw Huang TM: Dr. Kajal Gupta

Studies are ongoing in the efficacy of the dynamic twist control scheme. Recent calculations on an ONERA M6 wing show that the dynamic twist control scheme still works if shorter torque tubes are used, i.e., if the control torques are reacted in the inboard wing section rather than at the fuselage.

In addition to the dynamic twist concept, the relaxed-stiffness aeroelastic design concept proposed by Prof. Bendiksen is also under investigation. The preliminary results are very encouraging and suggest that a considerable reduction in the control torque and the wing structural weight are possible if the outboard section of the wing is designed with a relaxed torsional stiffness. In this test calculation, the stiffness of the outboard half of the wing span was reduced to 25% of its normal value, by reducing the modulus D of the plate insert correspondingly. This was accomplished by reducing the thickness of the outboard plate element to 0.63 of the inboard

(X-36..., continued)

The aircraft will be remotely controlled by a pilot in a ground station cockpit, complete with a head-up display (HUD). The pilot-in-the-loop approach eliminates the need for expensive and complex autonomous flight control systems.

Two 28 percent scale aircraft will be put through fighter aircraft maneuvers during the scheduled 25-flight program, in an effort to gather data on the performance characteristics (especially agility) of tailless, fighter-type aircraft.

The lack of both the vertical and horizontal tails on the X-36 greatly enhances the stealthy characteristics of the airplane, and holds promise of greater maneuverability than is currently available in existing fighter aircraft. The configuration also reduces the weight and drag of the aircraft, and will explore new flight control technologies. Initially, the X-36 will use a single-channel digital fly-by-wire control system originally developed by NASA. The ailerons will split to provide yaw control, and will raise and lower in a normal fashion to provide roll control.

value of 0.018. Compared to the neutrally stable nominal case with no twist control, h=0.025, the relaxed-stiffness wing has a structural weight of only 60.5% of the nominal wing.

Aerothermoelasticity and Aeroservoelasticity of a Generic Hypersonic Vehicle
PIs: Prof. Peretz P. Friedmann
Prof. Xiaolin Zhong (MAE)
GSR: Ira Nydick TM: Kajal Gupta

The study of hypersonic panel flutter has been completed. The aerothermo-servoelasticity of an unrestrained generic hypersonic vehicle is now being studied. The nonlinear hybrid system of equations, consisting of ordinary differential equations governing the rigid body motion coupled to partial differential equations governing the flexible motion, have been derived using Lagrange's equations in terms of quasi-coordinates. The vehicle flexibility is modeled using equivalent plate theory, which is capable of modeling elements of complex vehicle configurations, including general vehicle planforms, asymmetrical cross-sections, out-of-plane segments such as control surfaces, thermal loading, complex internal rib and spar structure, non-structural mass distributions, and components made of laminated composite material. Transverse shear effects and the ability to include general boundary conditions are also features available in the model.

The normal modes and frequencies of the vehicle will be obtained from the model and used to approximate the displacement field in the hybrid equations of motion. The equations will be first solved so as to obtain the appropriate trim state of the vehicle. The equations of motion will then be linearized about the trim state and the effect of rigid body dynamics and vehicle aeroelastic behavior will be explored in a comprehensive manner. Results will include a comparison of the flutter behavior of the constrained and unconstrained vehicle, and a detailed parametric study of the aeroelastic and aeroservoelastic behavior of the vehicle.

Bruins in the Desert

This past summer, UCLA's Daniel Landau and Jaime Sipila lived and worked up in the California high desert. Dr. Landau, of UCLA's Atmospheric Sciences Department under Prof. Wurtele, was (and continues to be) at Dryden as part of his NASA/NRC post-doc working with L. Jack Ehernberger on numerical studies of mountain waves, their propagation and breakdown into clear air turbulence. Currently, specific attention is focused on the impact of terrain geometry, terrain roughness, terrain vegetation, and turbulent boundary layers on wave development. Sipila, a second year graduate student in the EE department, worked in the Dryden flight controls group and submitted the following synopsis of his research efforts while at Dryden:

"For the past four months I've had the great privilege of working with Joe Pahle in the controls group. I was fortunate enough to spend three of those months working at Dryden in the WRAIF. Now I'm back at UCLA continuing my research and must admit I miss feeling the floor shake from sonic booms. There's nothing quite like it.

"The topic of my research is the control system design method known as eigenstructure assignment. Eigenstructure assignment is an extension of the well-known pole placement theorem. It gives the designer the additional authority of specifying a set of desired eigenvectors. Through this specification, a partial decoupling of system modes is possible, assuming certain minimum requirements have been met (controllability, etc...). For the next school year, Joe and I will be looking at extending the method to include the possibility of specifying a region of desired eigenvalues and eigenvectors rather than a specific set. With this, we hope to find an optimal solution in terms of robustness and feedback gain magnitude. If anyone would like further information, please email me at sipila@seas.ucla.edu and I will be happy to forward a copy of a report I wrote this summer."

Estimation of Wind Profiles From Laser Beam Propagation Distortion
PI: Prof. A. V. Balakrishnan (EE)
GSRs: Stan Shell, Gary Wang, Chi-Chao Chang TM: Dr. Ken Iliff

Much progress has been made in the collection of atmospheric scintillation data in the laboratory with an aim towards quantifying wind shear data. Long distance experiments across 7 meters (between beam source and detector) were performed using an improved experimental set up with results agreeing qualitatively with theoretical predictions. The new setup included a photodetector & amplifier all on a single integrated chip. Repeatability was also improved.

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The next phase on the experimental side of the project is near completion. In this experiment, the output of a 2-3 mW HeNe laser is coupled through a section of fiber optics and lenses to traverse across a variable length air path onto the photodetector. The detector (a photodiode coupled to a transimpedance amplifier) is placed within 12" of the beam source. Air/wind velocities vary from 0 to 20 m/s. Thus far, data has been collected and is currently being analyzed (using a spectrum analyzer, A/D converter, and FFT routine). Future plans include obtaining equipment to produce wind velocities up to 200 m/s in the laboratory, as well as possible flight tests at NASA Dryden using flyable hardware.

Modelling, Identification and Control With Applications to Flight Vehicles

PI: Prof. A.V. Balakrishnan (EE)
GSRs: Oscar Alvarez-Salazar, Jensen Lin
TM: Dr. Ken Iliff

This project studies the feasibility of using "Smart Structures" to improve airplane performance. Modeling and control of smart beams is currently under way. To aid the process of understanding structures with integrated & distributed sensors and actuators, a cantilevered beam was constructed. The beam was made of fiber glass. PZT wafers were embedded in the layup of the beam to act as the sensor and actuator. To date, experiments have been conducted to check "Continuous Models" of the beam. Active stabilization of the beam via rate feedback is also being tested. Other compensator designs will be studied and experimented with as well. Future work will include the study of "Smart Plates".

Optimal and Game Theoretic Synthesis for Short Takeoff/Vertical Landing Aircraft

PI: Prof. Jason L. Speyer (MAE)
GSR: Charles Dillon **TM: Bob Clarke**

Over the past year, we have been doing research in the area of optimal and game theoretic synthesis for Short Takeoff/Vertical Landing (STOVL) Aircraft. More specifically, we have been working on extending and enhancing the theory of robust adaptive control using disturbance attenuation, with application to linear systems with uncertain coefficients. This is particularly applicable to flight control systems in which the linearized dynamics may not be particularly well known in certain flight regimes, such as those which occur in high angle-of-attack and STOVL flight. Recently, using Hamilton-Jacob-Bellman theory, we have been able to extend the theory to infinite-time systems, as well as better characterize the resulting solutions, which will eventually lead to improvements in implementation. Some of the results of this work were presented at the 1996 AIAA Guidance, Navigation, and Control Conference in San Diego this past summer.